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13. ABSTRACT *(Maximum 200 words)*

The research investigated under this grant has focused on the basic problem of time-domain electromagnetic scattering and propagation in various physical environments. An issue of particular importance has been dispersion, and how it is manifested in the time domain, Particular dispersive environments that have been investigated are periodic and quasi-periodic propagation and scattering, short-pulse propagation in lossy, dispersive soils. With regard to this latter topic, a significant problem of interest involved short-pulse electromagnetic scattering from buried targets, with a focus on buried mines. The research on short-pulse wave phenomenology has motivated a new research thrust, in which the underlying phenomenology is exploited in the development of what has been termed "wave-oriented" signal processing. Particular signal processing algorithms that have been investigated including the Gabor transform, the wavelet transform, and windowed superresolution processing. In this context, we have also performed sophisticated Cramer-Rao bound studies to assess the ultimate accuracy of such algorithms when the data is contaminated with additive noise. Finally, the phenomenology is being exploited in the development of new wave-based time-frequency algorithms, in particular the wave-based methods of matched pursuits. This algorithm is very useful for the denoising of scattering data and is not being placed in the context of a decision-theoretic paradigm.

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I. Summary

The research investigated under this grant has focused on the basic problem of time-domain electromagnetic scattering and propagation in various physical environments. An issue of particular importance has been dispersion, and how it is manifested in the time domain. Particular dispersive environments that have been investigated are periodic and quasi-periodic propagation and scattering, short-pulse propagation in waveguides, and short-pulse propagation in lossy, dispersive soils. With regard to this latter topic, a significant problem of interest involved short-pulse electromagnetic scattering from buried targets, with a focus on buried mines.

The research on short-pulse wave phenomenology has motivated a new research thrust, in which the underlying phenomenology is exploited in the development of what has been termed "wave-oriented" signal processing. Particular signal processing algorithms that have been investigated include the Gabor transform, the wavelet transform, and windowed superresolution processing. In this context, we have also performed sophisticated Cramer-Rao bound studies to assess the ultimate accuracy of such algorithms when the data is contaminated with additive noise. Finally, the phenomenology is being exploited in the development of new wave-based time-frequency algorithms, in particular the wave-based method of matched pursuits. This algorithm is very useful for the denoising of scattering data and is now being placed in the context of a decision-theoretic paradigm.

II. Graduate Students

Several graduate students have been supported or partially under this research grant, leading to the successful completion of PhD disserations. The students and their dissertation titles are listed below.

1. Teng-Tai Hsu
Dissertation title: Frequency and time-domain analysis and signal processing of waves scattered from finite arrays

2. Stanislav Vitebskiy
Dissertation title: Ultra-wideband, short-pulse ground-penetrating radar

3. David R. Kralj
Dissertation title: Ultra-wideband, time-domain electromagnetics

III. Publications in which grant support is acknowledged

[1] L. Carin and L. B. Felsen, "Efficient numerical-analytic analysis of ultra-wideband plane wave scattering from a collection of strips," *Int. J. Num. Model.*, vol. 6, pp. 3-17, 1993.

[2] L. Carin and L. B. Felsen, "Time-harmonic and transient scattering by finite periodic flat strip arrays: Hybrid (Ray)-(Floquet Mode)-(MOM) algorithm and its GTD interpretation," *IEEE Trans. Antennas Propagat.*, vol. 41, pp. 412-421, April 1993.

[3] L. Carin and L. B. Felsen, "Design-oriented parametrization of truncated periodic gratings," *IEEE Microwave and Guided Wave Letts.*, vol. 2, pp. 367-369, Sept. 1992.

[4] L. B. Felsen and L. Carin, "Diffraction theory of frequency- and time-domain scattering by weakly aperiodic truncated thin-wire gratings," *J. Optical Soc. America A*, vol. 11, pp. 1291-1306, April 1994.

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[8] M. McClure, D.R. Kralj, T.-T. Hsu, L. Carin and L. B. Felsen, "Frequency domain wave-oriented data processing for scattering by nonuniform truncated gratings" *J. Optical Soc. America A*, vol. 11, pp. 2675-2684, Oct. 1994.

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[10] L. Carin, L.B. Felsen, and T.-T. Hsu, "Observable-based parametrization of time-harmonic fields excited by a truncated array of nonuniformly distributed phased line sources on an infinite dielectric slab," *IEEE Trans. Antennas Prop.*, vol. 44, pp. 56-66, Jan. 1996.

[11] L. Carin, L.B. Felsen, D.R. Kralj, H.S. Oh, W.C. Lee, and S.U. Pillai, "Wave-Oriented Data Processing of Dispersive Time-Domain Scattering Data," to appear in *IEEE Trans. Antennas Prop*

[12] L. Carin and L.B. Felsen, "Wave-Oriented Data Processing for Frequency and Time Domain Scattering by Nonuniform Truncated Array," *IEEE Antennas and Propagation Magazine*, June. 1994 (invited)

[13] T.-T. Hsu, L.B. Felsen, and L. Carin, "Wave-oriented processing of scattered field data from a plane-wave-excited finite array of filaments on an infinite dielectric slab," *IEEE Trans. Antennas Prop.*, vol. 44, pp. 352-360, Mar. 1996.

[14] S. Vitebskiy and L Carin, "Short-pulse plane-wave scattering from and the resonances of a dipole buried inside a lossy, dispersive half space," *IEEE Trans. Antennas Prop.*, vol. 43, pp. 1303-1312, Nov. 1995.

[15] D. Kralj, L. Mei, T.-T. Hsu and L. Carin, "Short-Pulse Propagation in a Hollow Waveguide: Analysis, Optoelectronic Measurement, and Signal Processing," *IEEE Trans. Microwave Theory Tech.*, vol. 43, pp. 2144-2150, Sept. 1995

[16] S. Vitebskiy and L. Carin, "Short-pulse plane wave scattering from a buried perfectly conducting body of revolution," *IEEE Trans. Antennas Prop.*, vol. 44, pp. 112-120, Feb. 1996.

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[18] T.-T. Hsu and L. Carin, "FDTD analysis of plane-wave scattering from microwave devices on an infinite dielectric slab," *IEEE Microwave and Guided Wave Letts.*, vol. 6, pp. 16-18, Jan. 1996.

[19] M. McClure, R. C. Qiu, and L. Carin, "On the superresolution identification of wavefronts from swept-frequency scattering data," to appear in *IEEE Trans. Antennas Prop.*

[20] S. Vitebskiy, L. Carin, M. Ressler and F. Le, "Ultra-wideband, short-pulse ground-penetrating radar: theory and measurement," to appear in *IEEE Trans. Geoscience and Remote Sensing*

[21] M. McClure and L.Carin, "Matched pursuits with a wave-based dictionary," submitted to the *IEEE Trans. Signal Proc.*

IV. Books Edited in which grant support acknowledged

1. H.L. Bertoni, L. Carin and L.B. Felsen, Ultra-Wideband, Short-Pulse Electromagnetics I, Plenum Publishing Co., New York, NY, 1993.
2. L. Carin and L.B. Felsen, Ultra-Wideband, Short-Pulse Electromagnetics II, Plenum Publishing Co., New York, NY, 1995.

V. Patents derived from this work

None